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The purpose of this study is to create a guide for technical review board chairperson conducting technical review boards for rocket testing performed by the Air Force Research Laboratory's Space & Missile Propulsion Division located at Edwards Air Force Base in California. Technical review boards are independent reviews of the test programs, providing a crucial check and balance in the program's overall systems engineering and quality process. As will be discussed in the subsequent pages, current technical review boards are inefficient and of inconsistent quality. The importance of a high quality, efficient technical review has never been more important due to the modern-era challenges relating to the limited hands-on experience and fewer number of current rocket testers. Thus a paradigm shift in the way technical review boards are conducted at AFRL for rocket test programs is needed. The local guidance created from this study is intended to assist in the execution of technical review boards. The guidance created by this study can assist the technical review board chairperson in running a more efficient and effective review. The guidance includes lessons learned about complexity of organizational decision making, policies, procedures, checklist, organizational cultural change, quality assurance, and meeting management. In addition, the checklist created as part of this guidance will assist in making sure the technical review board chairperson does not overlook a critical topic for review.

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Technical Review Board Chairperson Guidelines for Conducting Technical Review Boards for Rocket Testing

By

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Technical Review Board Chairperson Guidelines for Conducting Technical Review Boards for Rocket Testing

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TECHNICAL REVIEW BOARD CHAIRPERSON GUIDELINES FOR CONDUCTING TECHNICAL REVIEW BOARDS FOR ROCKET TESTING

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LIST OF ACRONYMS

AFMC – Air Force Materiel Command

AFRL – Air Force Research Laboratory

CSUB – California State University, Bakersfield

DTRs – Detailed Technical Reviews

IRB – Institutional Review Board

NASA – National Aeronautics and Space Administration

NCAR – Non-Conformance and Corrective Action Report

OPR – Office of Primary Responsibility

OSHA – Occupational Safety and Health Administration

P&ID – Piping and Instrumentation Drawing

SRB – Safety Review Board

TOP – Test Operating Procedure

TRB – Technical Review Board

TQM – Total Quality Management

VPP – Voluntary Protection Program

V&V Plan – Verification and Validation Plan

ABSTRACT

The purpose of this study is to create a guide for technical review board chairperson conducting technical review boards for rocket testing performed by the Air Force Research Laboratory's Space Missile Propulsion Division located at Edwards Air Force Base in California. Technical review boards are independent reviews of the test programs, providing a crucial check and balance in the programs overall systems engineering and quality process. As will be discussed in the subsequent pages, current technical review boards are inefficient and of inconsistent quality.

The importance of a high quality, efficient technical review has never been more important due to the modern-era challenges relating to the limited hands-on experience and fewer number of current rocket testers. Thus a paradigm shift in the way technical review boards are conducted at AFRL for rocket test programs is needed. The local guidance created from this study is intended to assist in the execution of technical review boards.

The guidance created by this study can assist the technical review board chairperson in running a more efficient and effective review. The guidance includes lessons learned about complexity of organizational decision making, policies, procedures, checklist, organizational cultural change, quality assurance, and meeting management. In addition, the checklist created as part of this guidance will assist in making sure the technical review board chairperson does not overlook a critical topic for review.

CHAPTER 1

Introduction

Introduction and Research Question

The Air Force's mission is to protect the United States from threats. While it is preferable to provide this defense as deterrent, the Air Force is always ready to fight for our freedom when necessary. Advanced weapons systems used by expertly trained Airman are a key element to the Air Force's success in a fight and therefore one of its greatest assets as a deterrent to war. In order to remain the most advanced Air Force in the world, this technology must be constantly improved upon and made available to the warfighter. According to Remen (2000), "The Air Force is always seeking to be a better warfighter, to always be ready and able to win if called to war, ensuring its systems are the best in the world." (p. 1)

Creating advanced technology requires vision and experimentation. Wiswell and Huggins noted (1990),

> "New weapon systems generally rely on technology developed by the laboratories which begins 10 to 15 years ahead of full-scale development. It is the laboratories innovative science and technology program that is the key to providing an affordable, qualitatively superior military force." (p. 7)

Continuously having the most advanced technology available requires long term commitment to research and development. The Air Force Research Laboratory (AFRL) is the embodiment of the Air Force's determination to have the most superior weapons systems available at all times. Remen wrote (2000),

> "The Air Force Research Laboratory is the Air Force's arm for conducting this research and development. AFRL has a long history of developing technologies to address the warfighter's needs and a long history of having those technologies leveraged or even outright used by both NASA and Industry and applied to their mission needs." (p. 5)

Remen observed (2000), "The military has always been the leader, first in Air then in Space, pushing what could be done in space." (p. 3) Early technical success of the Air Force Research Laboratory demonstrations provided the confidence required to proceed with the development of the Space Shuttle Main Engine (Wiswell & Huggins, 1990, p. 5) According to Remen (2000), "Every existing US space launch system, commercial and military, was derived from Air Force developed systems." (p. 3) However, the Air Force can't afford to be content with past successes and must continue to build for the future. Wiswell and Huggins declared (1990), "The laboratory is and will continue to fulfill its responsibility for developing technologies for future space and missile systems of the Air Force." (p. 6)

The Space Missile Propulsion Division of AFRL at Edwards Air Force Base has a long and proud history and is a world leader for the testing of rockets. Wiswell and Huggins reported (1990), "The Astronautics Lab started on Luehman Ridge east of the Edwards base as a part of the Air Force Power Plant Laboratory at Wright-Patterson AFB in Ohio for test and evaluation work." (p. 1) In 1952 the first facilities were completed and in 1959 the Power Plant Laboratory, Rocket Propulsion Branch was moved to Edwards (Wiswell and Huggins, p. 1). The Space Missile Propulsion Division has gone by many different names during its existence, but no matter the name the Space Missile Propulsion Division has been at the forefront of breakthroughs in rocket technology. The Space Missile Propulsion

Division has contributed to the success of the Saturn 5, Space Shuttle, Atlas, Titan, Minuteman, and Peacekeeper programs to name a few.

With a tradition of success on complex cutting edge technology programs it is easy for an organization to get lulled into a sense of complacency. But there are new challenges that have emerged and many of them are not research related. One of these is the decreasing workforce available to perform all the various tasks required to meet the challenges of highly complex technical work involved in rocket testing. Additionally, a large part of the corporate knowledge base created during the 50's and 60's, the glory days of the rocket industry, has disappeared because of retirement. With a significant reduction in rocket programs and the number of rocket tests each year, the new generation of rocket testers is finding fewer learning opportunities. This has resulted in test programs being performed by fewer and often less experienced testers than previous generations, which has increased the importance of the Technical Review Board (TRB) process. This study will look at the TRB process in order to find ways to improve it.

Technical review boards are independent evaluations of the test programs, providing a crucial check and balance in the program's overall systems engineering and quality process. The Air Force Research Laboratory conducts technical review boards to reduce risks to programs and personnel. AFRL is interested in improving the TRB process as part of the laboratory's continuous quality improvement program to assure future test program success by adapting to a changing environment and incorporating lessons learned. Air Force regulations are vague about how TRBs are to successfully evaluate the technical aspects of a program. Current TRB reviews are inefficient and the quality of the review provided is

inconsistent from one TRB to the next. Can detailed local TRB guidance be created that will improve the quality and efficiency of TRB reviews for rocket test programs at AFRL?

Brief Background

Air Force regulations require test programs to have technical review boards. These reviews are intended to provide greater confidence the test program will succeed. Due to the expense of tests and inherent dangers associated with testing rockets, Air Force management places a high level of importance on technical review boards being conducted. Because of the small margin for error and potential for catastrophic failure, quality technical reviews are crucial to continuing the high level of success test programs have seen at AFRL.

The Space Missile Propulsion Division has to comply with four levels of guidance on technical review boards, based on its placement in the Air Force hierarchy. The Air Force is split into different commands. AFRL is the laboratory organization of the Air Force Material Command (AFMC). AFRL is broken into directorates, which are further broken down into divisions. The Space Missile Propulsion Division is part of the AFRL Propulsion Directorate. The Air Force, AFMC, AFRL, and the Edwards portion of the AFRL Propulsion Directorate, AFRL/RZ-West, all have guidance created for TRBs.

The four regulations flow from the highest level organization down, and therefore there is a large amount of repetition in the wording. Select portions of each regulation's wording has been included here in order to highlight what the regulations include without boring the reader with redundancy. The highest level regulation is the Air Force Instruction 99-103, Capabilities-Based Test and Evaluation which states the following related to technical review boards (2009), "The TRB assesses the soundness of system design and test plans to reduce test risk. " (p. 45) The instruction does not provide any details about how to

assess the soundness of the designs or test plans, but it does state a goal which is to reduce test risk. The next level of regulation is the AFMC Instruction 99-103, *Test Management*, which states (2004), "The technical review will verify that the overall method of test and test data acquisition is adequate to evaluate the requirements and to verify objectives can be met with acceptable risk." (p. 4) The AFMC instruction provides a little more direction on the goal of reducing risk by stating that objective can be met with acceptable risk, although what is acceptable is not clarified. The AFMC regulation also fails to provide details about how to go about verifying the overall method of test and test data acquisition is adequate to evaluate the requirements. The third regulation is the AFRL Instruction 61-103, AFRL Research Test Management, and it states (2007), "As a minimum, technical reviews will assess test requirements, techniques, approaches, schedules, and objectives." (p.11) The AFRL level instruction provides a small amount of insight for the review board member of what they are to assess, but does not provide any criteria for the assessment. The final regulation is the AFRL/RZ-West Operating Instruction 61-103, Research and Development Test Operations, which states (2010),

> "11.0 Technical Review Boards (TRB): The TRB is responsible for reviewing the technical soundness of the facility systems design, verification and validation plan, test plans, NCARS, procedures, and test readiness data to evaluate if the program will meet the test requirements and program risk…" (p. 9)

The AFRL/RZ-West operating instruction provides details where to find the information to be evaluated and includes reference to the verification and validation plan (V&V plan). The V&V plan and its importance will be discussed further in chapters 2 and 4.

As can be seen, all four Air Force regulations which define TRBs are vague about how to perform a successful review or about the exact goals of the review. Qualitative words like “soundness”, “method”, “adequate”, and “acceptable” are used. This vagueness is intentional due to the variety of different technical programs the Air Force conducts and the need for flexibility due to these differences. Even within programs solely within the Space Missile Propulsion Division, there is a large range of types, to include the testing of large rocket motors, new propellants, or advanced materials to name a few. Despite these diversity on can find a large number of similarities between rocket test programs, which would justify having a single standard TRB. This paper will explore TRBs for rockets tested by the Space Missile Propulsion Division.

Two of the main competing values related to TRBs are thoroughness and efficiency. The challenge for any test program is finding the point where attention to detail is sufficient and must give way to schedule considerations. The rockets being tested are often multimillion dollar assets and test failure could lead to loss of the asset or the desired data. At the same time schedule delays can cost thousands of dollars a day to retain defense contractor expertise or by delaying a launch that is dependent on the test results. In the past, thorough TRBs have required a large investment in time and resource. One test program had TRB boards that meet once or twice a week for 6 months. Another test program chose to relocate to another test facility due to the $75,000 estimate for the TRB, which was approximately a third of the total test costs. Proponents of thorough TRBs are concerned with technical issues not being missed because of the inherent dangers and large costs associated.

TRBs that have been considered efficient have been defined so because they required small investments in time and resources. Proponents of efficient TRBs are concerned with available resources and schedules. This concern is increased because resources, especially personnel, are shared between programs. It is my opinion, a balance must be found between the extremes of an efficient review versus a thorough review.

Recent test activities have revealed shortcomings in the effectiveness of the TRB process. For example, it was found that one particular TRB for a large rocket program concentrated on procedure review and spent very little time evaluating the system design. System design errors could have lead to personnel being exposed to dangerous chemicals. Even though this is the most extreme consequence, the more common scenario would be that the design errors could lead to test failure or loss of test data. One of the reasons TRBs are conducted is to find design errors before they impact the test program.

First, a problem myself and others who participate in TRBs have identified is that they are not an efficient use of participants time. This is due partially to poor meeting management. The other part of this problem relates to the current practice of having all topics discussed at meetings that include all or most of the review board members, even if not all members have an interest or expertise in the topic being discussed. Some will argue that having everyone in the meeting discussing every topic leads to input that otherwise would go unheard. This is true, but my experience has shown the overwhelming majority of useful comments on any topic being discussed come from those with expertise in that topic. The overall effect of the current practice is to cause board members to become disengaged during portions of the reviews, and to significantly limit the amount of topics a TRB can review due to the lack of ability to review multiple topics simultaneously.

Second, my observations of the TRB process have revealed that too much time is being spent during TRBs going through procedures step by step, while not spending enough time on review of the system design and analysis. Years ago, TRBs started placing a high level of emphasis on procedure review due to programs generating very poor quality procedures. As a result, review of system design and analysis became secondary and on some programs not even a part of the TRB review. A pattern was observed where programs with experienced test directors had good procedures and programs while those with inexperienced test directors had poor quality procedures. Recent changes in AFRL practice have required test directors to be experienced in rocket testing. Additionally, last November, a local procedure writing guidance was created to standardize and improve the quality of procedures. These changes should allow the TRBs to reduce the amount of time spent reviewing procedures, which should be redirected to review of system design and analysis.

Significance of the Topic

The majority of the firsthand knowledge for testing rockets during the glory days of the rocket industry was possessed by those no longer part of the workforce. The current rocket testers have gained experience based on a far smaller number of rocket tests. While the current generation has benefitted from the experience documented by those that have gone before them, they are at a disadvantage due to the small number of learning opportunities resulting from the significantly reduced number of rocket tests. The importance of a good quality technical review has never been more important in order to continue successful testing and protect lives due to the limited hands-on experience of current rocket testers.

Hands-on experience is not the only new challenge rocket testers face, they are also performing test with far fewer test personnel. The number of test personnel has decreased drastically over time due to downsizing. This has resulted in there being a very small pool of individuals available to provide technical expertise related to rocket testing. These individuals are busy and time spent on one program usually means it is being taken away from another program. There is rarely any depth of experienced personnel on a test program anymore. Now more than ever it is important for TRBs to be managed efficiently.

A paradigm shift in the way technical review boards are conducted at AFRL for rocket test programs is needed. Despite the differences between rocket test programs, there are still a large number of similarities which would allow for detailed local TRB guidance to be created. Without detailed local guidance, TRBs could miss important technical and safety issues with a program, which could lead to test failures or personnel being harmed.

Stakeholders

The main stakeholders related to technical review boards for rocket test programs performed by the Space Missile Propulsion Division are the following:

- AFRL Management
- Technical Review Board Members
- Test Personnel
- Other Government Agencies That Test Rockets
- Aerospace Industry
- Taxpayers

AFRL management creates the technical review boards and relies on the review boards to provide them with an independent assessment of the programs ability to meet the technical objectives. These reviews must consistently provide AFRL management with high quality feedback for the process to work effectively. Poor quality technical reviews could

lead to problems for the program and management, such as personnel being injured or equipment being destroyed.

Technical review board members, including the technical review board chairperson, invest a great deal of time and effort reviewing programs. Review board members are selected because they have expertise in some portion of testing, similar to the program they are reviewing and therefore are very interested in the quality of the reviews. Review board assignment is a duty assigned to someone in addition to their regular responsibilities.

Test personnel include program managers, test engineers, technicians, etc. Test personnel are directly responsible for program success. Test engineers design and/or review the facility design and analysis. Test personnel write the procedures and perform the system checkouts. Test personnel create and/or review all documents which are given to the review board. Additionally, as discussed in the previous section, technical problems can turn into safety problems, and test personnel are those most likely to be affected by a safety problem.

Other government agencies like the Navy, the Army, the Missile Defense Agency, and NASA all have rocket programs. The aerospace industry receives funding from government agencies to build and test rockets. Many of the tests conducted by the Space Missile Propulsion Division are for rockets funded and/or developed by one of these agencies. Additionally, a failure at any test site can have repercussions for the entire rocket test community. For example, a catastrophic failure can lead to new safety or procedural requirements, costly upgrades to facilities, or schedule delays similar to what happened when the Space Shuttle Columbia blew up.

Most rocket test programs are funded by the government. Successful technical reviews find problems before they happen saving time and resources. When programs fail it

usually cost the taxpayers by diverting funds from other programs or abandoning the research the program that was being worked.

Overview of the Thesis

Chapter 2 of this thesis is the literature review. The literature review is broken into four sections: Complexity in organizational decision making; Varieties of coping mechanisms; Organizational culture change; and Meeting management. Complexity in organizational decision making and varieties of coping mechanisms were chosen in order to understand and find ways to deal with the complex decisions technical review boards must make. The topic of organizational culture change was studied to find effective methods of implementing changes to existing processes. Meeting management was selected to find more efficient ways to conduct TRB meetings.

Chapter 3 lists the methodology for this thesis. Chapter 3 begins with a reflection of my personal experience related to the TRBs. It is then followed by a discussion of the literature review and where the literature was obtained. AFRL is a secured location and requires documentation to be approved for release, so the third section describes the AFRL public release process. In addition, federal law requires all research to be evaluated to make sure human research subjects are treated ethically or verified that no human subject are involved. The chapter finishes with a section on the CSUB Institutional Review Board (IRB) process and explains how this study was not to be human subjects research.

Chapter 4 is the findings and contains the recommend detailed local TRB guidance for rocket test programs to assist TRB chairperson conduct a successful review. The guidance includes:

1. A standard listing of items to be reviewed to assist TRB chairperson in making sure no topic is missed.
2. How to plan and organize a TRB in order to perform a more comprehensive review.
3. Suggestions on how to hold efficient meetings and perform proper resource management.

Chapter 5 is the summary and conclusions. This chapter also contains recommendations for future work.

CHAPTER 2

Literature Review

Overview

This literature review is broken into four categories, with the first section pertaining to complexity in organizational decision making. The second section is on varieties of coping mechanisms, and explores the use of policies, procedures, and checklists as a way to deal with the complexity in organizational decision making. The third section is on organizational change, and it examines the topic of quality processes including Total Quality Management (TQM). The final section is on meeting management, and was included to find more efficient and effective ways to conduct meetings. The majority of the literature was found in the ProQuest database, which is a large research database available to CSUB students. Other sources were obtained from internet searches, professor recommendations, reading from previous class work, and references listed in other articles.

Complexity in Organizational Decision Making

This section will examine topics related to complexity in organizational decision making. The literature on this subject includes the need for networking, the need for guidance, purpose of polices, and issues associated with unwritten policies.

Our volatile and dynamic world is changing at an amazing rate due to new technologies and the availability of new forms of instant communication. Skaržauskienė stated (2010), “The environment in organizations is becoming more complex and changes more often and suddenly (Tvede, 1997; Stacey, 1993; Goswami, 1993; Tetenbaum, 1998; Laszlo, 2002).” (p. 50) Weber and Khademian relayed (2008), “As early as 1967, scholars

and practitioners from different disciplines recognized that the dynamic complexity of many public problems defies the confines of established "stovepiped" systems of problem definition, administration, and resolution (Churchman 1967; Rittel and Webber 1973; Roberts 1997, 2000, 2002b)." (p. 336) Weber and Khademian's comments were in the context of the need for networking between different government agencies, but it applies to different departments within an organization. Technical review boards require multidiscipline membership to help prevent stovepiping and the guidance for conducting a TRB is intended to establish a better way of defining, administering, and resolving the problems presented to the TRB.

As seen from the previous paragraph, stovepiping can be an organizational concern, in a sense, stovepiping types of knowledge can be just as big of a problem. Schmidt relayed (1993), "We need to remember that all kinds and sources of knowledge are not superior nor inferior but simply different ways of perceiving and organizing our limited understandings of a rich and complex reality." (p. 530) Schmidt's reminder that our complex world requires different perspectives is very important to the success of the technical review board success. The TRB process will break down if any participant in the TRB process starts to believe their knowledge or sources of knowledge are superior to others.

Giving considerations to all types and sources of knowledge is not an easy task, therefore tools to assist in the processing of this information would be helpful. Brown found (2010), "Public Managers typically operate in highly dynamic and complex environments and need decision-making heuristics to simplify that complexity." (p. S213) The TRB guidance created by this study is designed to be an approach that helps the TRB chairperson simplify the complex TRB process.

Schlarman states (2010), “Policies are the first line of defense against risk from an organizational perspective.” (p. 1) Schlarman wrote (2010), “The ultimate goal of setting policies is to influence behavior, set clear requirements and guide people through business decisions.” (p. 3) While the Air Force does have regulations for TRBs these regulation are too vague to accomplish the goals that Schlarman presented for setting policies. The reason I chose this topic of creating guidance for the TRB chairperson is to provide the level of detail needed in addition to the Air Force regulation to accomplish this goal.

Now with the goal in mind we will examine the current state of the organization with regard to TRBs. According to Van Dusen (2006), if you are a small organization then policies may be “understood” even if not in writing. The Air Force Research Laboratory is not a small organization, and for large organization like AFRL “understood” procedures can’t possibly work as there is no way to make sure everyone has the same understanding. Van Dusen argued, “Relying on ‘understood’ policies, however, may lead to misunderstandings.” (p. 59) It is my opinion, that AFRL works to “understood” policies on how to conduct TRBs. Many AFRL personnel would state that they understand the purpose and how TRBs are to be performed successfully. Recent experience has shown that there is little consistency in regards to AFRL personnel’s understanding of the TRB process. This has led to misunderstandings and inconsistencies in how TRBs are performed, evaluated, and presented to management. Van Dusen stated, “Just imagine the kind of resentment and frustration a situation like this might create” (p. 59). This situation has caused arguing between personnel involved in TRBs. Additionally it can focus the reviewers and test team on the arguments instead of the concentrating on what needs to be done. Van Dusen concluded, “On an organization-wide basis, this can mean lower morale and productivity,

more grievances and understandably poor relations between supervisors and employees" (p. 59). If you substitute supervisors and employees for review board members and test team, this statement sums what sometimes happens at TRBs.

While the previous paragraph explains the issue related to AFRL working with "understood" policies, it is important to note that the belief that everyone understands the policies will lead to resistance to any specific guidance being accepted. Semel, Bader, and Gawande acknowledged (2010) "Successful implementation entails local system change. But there is evidence that such efforts can produce substantial benefits." (p. 2355-2356) The need for cultural change will be explored more in the section on organization cultural change.

This section examined several concepts related to complexity in organizational decision making. The lessons learned from this section include the importance of multidiscipline reviews, being receptive to different forms of knowledge, and the significance of having written policies. The next section will look into various coping mechanisms an organization can use to handle these complexities in organizational decision making.

Variety of Coping Mechanisms

This section will explore ways organizations can handle the complexities that are part of everyday organizational decision making. The literature on this subject includes why policies, procedures, and checklists are needed and what makes a good checklist.

From How to Write a Policy Manual, "A policy is a predetermined course of action established as a guide toward accepted objectives and strategies of the organization" (p. 5) According to Gawande (2009), "..The volume and complexity of what we know has exceeded our individual ability to deliver its benefits correctly, safely, or reliably." (p. 13)

Van Dusen contended (2006), "Another reason for developing a policy manual is the increasing difficulty of managing and controlling complex operations." (p. 62) Van Dusen wrote (2006), "A policy manual is an excellent training resource." (p. 61) AFRL has recently started to compile a Test Operations Handbook in part to be used as a training resource. This study will create a Test Operations Handbook section on how to conducted a TRB and include a checklist of possible review topics to assist the TRB chairperson in managing the complexities involved.

In *The Checklist Manifesto,* Atul Gawande explains why checklists for surgery are needed and the logic is applicable to a technical review board checklist. Gawande observed (2009),

> "Yet it is far from obvious that something as simple as a checklist could be of substantial help. We may admit that errors and oversights occur – even devastating ones. But we believe our jobs are too complicated to reduce to a checklist." (p. 34-35)

Gawande states one of the reasons checklist are needed (2009), "The first is the fallibility of human memory and attention, especially when it comes to mundane, routine matters that are easily overlooked under the strain of more pressing events." (p. 36) Gawande further explains (2009), "…people can lull themselves into skipping steps even when they remember them. In complex processes, after all, certain steps don't always matter." (p. 36) Gawande concludes (2009), "Checklists seem to provide protection against such failures. They remind us of the minimum necessary steps and make them explicit. They not only offer the possibility of verification but also instill a kind of discipline of higher performance." (p. 36) Olson and Kelly wrote about checklists (2005), "Expert knowledge

should be documented because experts can leave your organization, taking precious organizational knowledge with them." (p. 60)

I found Gawande's description of what makes a bad checklist and good checklist to be accurate, matching my personal experience with checklists. Gawande explains (2009),

> "Bad checklists are vague and imprecise. They are too long; they are hard to use; they are impractical. They are made by desk jockeys with no awareness of the situations in which they are to be deployed. They treat people using the tools as dumb and try to spell out every single step. They turn people's brains off rather than turn them on.
>
> Good checklist, on the other hand, are precise. They are efficient, to the point, and easy to use even in the most difficult of situations. They do not try to spell out everything – a checklist cannot fly a plane. Instead, they provide reminders of only the most critical and important steps – the ones that even the highly skilled professionals using them could miss. Good checklist are, above all, practical." (p. 120)

When creating a checklist the obvious question is what should be considering in the design of the checklist? Again Gawande provides guidance (2009), "A checklist cannot be lengthy." (p.123) Gawande reports (2009), "People start "shortcutting". Steps get missed. So you keep the list short by focusing on what he called "the killer items" – the steps that are most dangerous to skip and sometimes overlooked nonetheless." (p. 123) Gawande states (2009), "The wording should be simple and exact…." (p. 123)

In the previous paragraph the discussion on checklist centered around what elements make a good checklist. The lessons in this paragraph are related to the purpose of the

technical review board and one of the key items the review board evaluated. Part of the AFRL test process requires test programs create a verification and validation plan (V&V plan). The V&V plan lists the inspections, analysis, and functional checkouts that will be performed to provide confidence the test will be successful. While not in the standard checklist format, the V&V plan is essentially a checklist designed to assist the test team in finding defects before they affect the test. From the field of software engineering comes an interesting perspective on checklists. In the article *A Statistical Approach to the Inspection Checklist Formal Synthesis and Improvement* the Chernak presents the elements needed in an inspection checklist to detect flaws in software. Chernak found (1996),

> "However, according to our experience, an inspection process becomes more productive and the inspectors find more defects when a checklist is represented by two components. The first component is of a "Where to look" category and means a particular feature of a work product. It should lead the inspector to a specific "spot" in the work product where a given rule is implemented. The second component is of a "How to detect" category." (p. 867)

Chernak stated (1996), "Hence, a defect model should have one more attribute – type of inspection." (p. 868) Basically the V&V plan should be designed to find "defects" that would lead to failure. One of the main tasks of the TRB is to evaluate whether the test team's following the V&V plan will lead to a high level of confidence of technical success. The TRB guidance should include verifying that the V&V plan includes information on where the requirements come from, how to detect compliance, and what type of inspection, analysis, checkout or combination of these will be used to verify the systems are ready for test.

This section explored coping mechanisms for dealing with the complexities organizations face. The lessons learned from this section included reasons for having policies, elements of good and bad checklists, and advice that can be used for the review of the V&V plan. The next section will examine organizational culture change and how lessons from the quality assurance community, including how to get employee buy-in, can shed light into effective ways to bring about change in an organization.

Organizational Culture Change

This section will look into the topic of organizational culture change. The literature on this subject includes a review of quality process with an emphasis on total quality management (TQM). Total Quality Management (TQM) is a quality assurance philosophy based on W. Edwards Deming 14 points. Deming's teachings are credited for much of the quality improvements in the Japanese auto industry.

There is a lot of debate if TQM as a whole can be applied to the public sector, but there is little doubt that parts of TQM can be applied to the public sector. Swiss reported (1992),

> "TQM has been endorsed by President Bush, who said, 'Reasserting our leadership will require a firm commitment to total quality management and the principles of continuous improvement…. Quality improvement principles apply…to the public sector as well as private enterprise' (Car and Littman, 1990, p.2)" (p. 356)

For the purposes of this paper the debate of applying TQM as a whole to the public sector will be ignored and only the portions of TQM and other quality principles that can be applied directly to the TRB process will be considered.

Swiss found (1992), "…quality requires total organizational commitment." (p. 358) The current management environment of AFRL is committed to quality and continuous process improvement. The AFRL has joined the OSHA Voluntary Protection Program (VPP), which parallels the TQM process but with an emphasis on safety instead of quality. Tompkins warns (2005), "Without a fundamental change in culture, longstanding priorities and behaviors will persist." (p. 345) The principles of the VPP program include employee engagement and allowing those at all levels of the organization to play an active part in creating a safe environment with the support of management. AFRL has been in the process of cultural change as part of the VPP program where employees are starting to see they can personally make a difference and are receiving management support, and the success there will easily transfer to quality process.

According to Swiss (1992), " …quality improvement requires strong worker participation." (p. 358) Tompkins wrote about one of Deming's 14 points (2005),

> "**Remove barriers to pride in workmanship.** People want to take pride in their work. It is a primary source of motivation. Yet little pride can be taken where workers are subject to rules and policies that make no sense, reward systems that are geared to quantity rather than quality, and no opportunities to help improve the system." (p. 341)

One of my many criticism of TRBs from the test team perspective has been that the test team is often unable to take pride in their work due to the review board making review board member's preferences requirements. This has often caused test personnel to put minimal effort into documents that will be reviewed by the boards. They believe that the review board will take ownership of anything created, therefore making the effort a waste of time.

The current VPP environment has given new hope that test personnel will have an opportunity to help improve this process, because of the emphasis the VPP program puts on having management support those closest to the work getting the support required to make improvements. Tribus quoted Deming as having said (1996), "Inspection does not build quality, the quality is already made before you inspect it. It's far better to make it right in the first place." (p. 10) The TRB guidance created by this study should include a separation of the roles and responsibilities to clearly define who, test team versus review board, is responsible for what. By empowering the test team, they will be more motivated to create better quality products in the first place.

All the discussion in the previous paragraph about employee participation, motivation, and empowerment applies equally to review board members as it does to test team members. My experience and observation of others who have participated as review board members shows that review board members want to contribute to the success of a program. Review board members are participating in addition to their normal workload and therefore would like their time spent efficiently during the review process. The next section will discuss meeting management, which is one way to efficiently use review board members time. From lessons learned by NASA, Harkins stated (1999),

> "As a precursor to the design review, *detailed technical reviews* (DTRs) are recommended for important products to facilitate early detection and correction of design deficiencies. DTRs are informal, working-level, peer reviews…The primary differences are the greater technical depth provided by the DTR, the corresponding higher specialization of the small (commonly 2 to 3-person) review team…" (Review Procedures section, para. 2)

The design review presented by Harkins is similar to a TRB. DTRs do not officially exist for programs within the Space Missile Propulsion Division. Many programs perform unofficial peer reviews, like the DTRs, by having several test team members review and comment prior to material being submitting to the review board. These programs in my experience have generally had shorter TRB reviews due to better quality starting documentation. Based on the NASA lessons learned and personal experience, I would recommend requiring documentation to be submitted to review boards with a peer review page signed by at least two test team members other than the author of the document.

As discussed in the previous paragraphs, a test team creating poor quality documentation is a problem but just as big of a problem is the acceptance of poor quality materials that are submitted for review. Swiss reported (1992), "Accordingly, TQM generally opposes mass inspection of products because such inspections provide a safety net that shifts quality responsibilities away from the initial designers and producers." (p. 357) Sometimes the poor quality initial documentation being submitted to the review boards is more related to the safety net issue Swiss presents. If the review boards are going to spend days or months reviewing the test team's documentation, regardless of its initial quality, there is little incentive to put a lot of effort into the draft submitted. The first recommendation I have from reading Swiss statement is for TRB chairperson not to accept poor quality documents for review. Instead the chairperson should send the document back to the test team for improvement. If the test team continually produces poor quality documentation, then the TRB chairperson should request the AFRL West Test Lead and/or responsible branch chief to provide the test program with someone with the required expertise to assist. The second recommendation is that the TRB not review all

documentation in detail. Each document should only receive the amount of review that is required, unless the review finds major flaws.

This section has explored the problems of quality documentation, now the focus shifts specifically to the documentation of requirements. Requirements for rocket test programs come from many sources to include, but not limited to, the test plan, regulations, policies, and best practices. According to Deming (1952-1953), "'Good quality' and 'uniform quality' have no meaning except with reference to the customer's needs." (p. 430) The customer's needs are documented in the test plan. The TRB's job is to verify that the test plan requirements can be met. Hoyer and Hoyer quoted Phillip Crosby (2001), "That is precisely the reason we must define quality as 'conformance to requirements' if we are to manage it." (p. 54) Hoyer and Hoyer stated (2001), "Somehow, someone must know what the requirements are and be able to translate those requirements into measurable product or service characteristics." (p. 55) Requirements no matter the source, test plan, regulation, best practice, etc., are translated into the V&V plan.

As previously stated, one of the primary functions of the TRB is to evaluate the effectiveness of the verification and validation plan (V&V plan). The V&V plan is the test teams approach to ensuring technical success of the program. The V&V plan tells what inspection, analysis, and functional checkouts will be performed. Deming wrote (1947), "The problem of validity is one of the proper approach to the problem, to discover what information is wanted and to find out how to draw it out if it can be had." (p. 147) Deming concludes (1947), "In short, it is the problem of eliciting the right answers to the right questions." (p. 147) The TRB is required to evaluate whether following the V&V plan will

provide a high likelihood of success. Basically, is the approach proper to the problem and will that result in the right answers?

This section looked into organizational culture change by reviewing the literature on quality processes. The lessons learned from this section included the need for test team and review board member roles and responsibilities, peer reviews, and the end of the acceptance of poor quality documentation. This section finished by focusing on the V&V Plan. The next section will explore the topic of meeting management.

Meeting Management

TRB meetings at AFRL tend to be long, drawn out meetings, often taking what should be completed in less than two hours and stretching it into half day or full day events. Lee found (2008), "Just as good project management makes for a successful project, proper management of meetings makes them more successful." (p. 25) Landale wrote in regards to meetings (2004), "They have to deal with the essentials, fast and effectively, and this requires a completely different focus for both the person facilitating the meeting and from attending participants." (p.26) Landale quoted Rob Cram, STC's managing director, as having said (2004),

> "Getting radical with meetings means ending this complacent practice and, instead, working with action-oriented objectives. This approach focuses on the business priorities that the team needs to resolve and requires that every participant come to the meeting with 'thought through' ideas on how this can be achieved." (p. 26)

The first lesson on meeting management taken from the literature is to make meetings focused with action-oriented objectives.

Allen, Rogelberg, and Scott pose several questions that should be asked about meetings, the first of which is (2008), “Can topics of meetings be handled through e-mails?” (p. 50) A lot of topics that are part of the TRB process can be handled through e-mail, so the lesson here is “don’t meet”. Allen et al. also asked (2008), “Do real outcomes and action items result from the gathering?” (p. 50) Often TRBs become regularly scheduled meetings until completed, but if there is no expected outcome or action items from any particular meeting then that meeting should be cancelled. Allen et al. further asked (2008), “Was any assigned pre-work completed? Were action items accomplished from a previous meeting?” (p. 50) If the required documents have not been completed prior to the TRB or the action items from the previous meeting have not been completed, then don’t meet. Allen, Rogelberg, and Scott’s advice seems to be common sense and obvious, but stopping to answer these simple questions could save a lot of time.

All the authors that discussed meeting management wrote about the importance of agendas. Kloppenborg and Petrick contended (1999), “The agenda should include logistics issues (date, time, and place), the meeting purpose, announcements, decisions, discussions, summary, path forward, and evaluation (+/Δ) sections.” (p. 172) Lee reported (2008), “Write the agenda with action words stating what the participants will do at the meeting.” (p. 27) Allen et al. agrued (2008), “The agenda should start with the most critical and strategic items.” (p. 52) Staren wrote (2009),

> “It is important to specify an agenda for each meeting so that participants can plan and prepare appropriately prior to getting together. The chair should request input from all members regarding agenda topics and should do so with adequate time prior to the meeting.” (p. 82)

According to Kloppenborg and Petrick (1999), "Individual participant or committee reports can be attached to the agenda with progress reports on projects that are publicly anticipated." (p. 172) In the case of TRBs these reports will often be the document the test team has created for review or prep work performed outside the meeting.

Lee maintained (2008), "Work outside the meeting room gets accomplished to carry out the meeting's purpose." (p. 28) Current Space Missile Propulsion Division practice for TRBs is for documents to be reviewed outside the meeting and for the members to come together to discuss everyone's comments. A large number of the comments don't require any discussion and it would save meeting time if all document reviews were given to the test team to incorporate outside the meeting, saving time in the meeting for only topics that required discussion. Landale argued (2004), "It requires that every participant in every meeting comes ready to add value. It also requires people to have thought about, and arrive ready to speak about, the business objectives under discussion." (p. 26) Due to busy work schedules it is not uncommon for some TRB participates to come to the meetings unprepared. This practice is wasteful and should be discouraged. Allen et al. stated (2008),

> "**Provide an opt out clause.** Organizations should make it OK for employees to opt out of meeting that have little to do with their tasks or expertise, imagine the cost savings of meeting with only the people who need to know, as opposed to the whole group or team." (p. 52)

Review board members being unprepared for the meeting can also result from the meeting having little to do with their expertise and Allen, Rogelberg, and Scott's opt out clause could save time. The current Space Missile Propulsion TRB practice is to meet with as whole a group as possible for every topic discussed. Meeting with only the people who know would

be of great valued to board and test team members by eliminated the need to get the unprepared review board member up to speed. Furthermore, by allowing an 'opt out' rather than 'not inviting' means that the team members lack of attendance is acknowledgement of agreeing to the outcome by the present TRB members.

Going back to some of the principles presented earlier in this section, meetings should result in decisions and action items. Lee and Lazarus wrote (1993), "Agree on follow-up actions. This is done by clearly defining what they are, who will be responsible for them, and when they will be completed." (p. 11) According to Lee (2008), "Assigning actions gives members the opportunity to contribute at an individual level and ensures personal responsibility and accountability for achieving the overall purpose. Having due date lets the members plan their time outside the meeting for personal productivity." (p. 28) TRBs should assign more individual responsibilities to the board members by assigning action items to be performed outside of the meeting allowing all board members to contribute to the process. Staren contended (2009), "Subsequent to the meeting it is essential that the group is sent accurate, organized minutes in a timely manner." (p. 83) These meeting minutes should include the action items, who is responsible, and the due dates.

Allen et al. give us this warning about trying to change meeting behavior (2008), "Meeting behaviors and practices are often well-learned, institutionalized habits that can be difficult to break." (p. 52)

This section examined the topic of meeting management. Lesson learned from the literature included having action-oriented objectives, when to meet, and the importance of agendas and meeting minutes.

The literature review looked at the topics of complexity in organizational decision making, variety of coping mechanisms, organizational culture change, and meeting management. The complexity in organizational decision making stated the criticality of guidance as created as a result of this study. The variety of coping mechanisms, organizational culture change, and meeting management sections provided advice on specific items to be included in the guidance.

CHAPTER 3

Methodology

Experience and Best Practices

A significant portion of the guidance created will be based on personal experience, but backed by examples from literature and sound systems engineering. I have been involved with the TRB process, and its predecessor the technical evaluation committee, for fourteen years. I have served as both a TRB member and TRB chairperson. In addition, my experience on the program side has been as test director, test conductor, or program manager of programs going through a technical review. Additionally, I have recently served as the lead for an internal technical investigation which offered a unique perspective for reviewing TRBs after they have been completed. The experience with the internal technical investigation lead to insights and conclusion about the TRB process that otherwise I would not have had. The investigation revealed to me that missing one design error could result in personnel being exposed to dangerous chemicals, luckily it did not happen in this case. This was despite the months of review that were spent examining the procedure line by line. Also the investigation, showed me how different review boards focus on different topic and allowed me to reflect on how few perform a thorough design review unless prompted by the test team or management.

Over the years I have been involved with numerous discussions with AFRL personnel on the topic of TRBs and how to improve them. I have not taken any actions up until recently, when AFRL management tasked me with reviewing and creating local guidance related on the subject of rocket testing. Most of my initial interest was related to the process, knowledge of the process, tasking to create local guidance, and need to write a thesis for my

masters. My goal is to improve and standardize the Space Missile Propulsion Division's approach to technical review boards in order to prevent test failures and personnel injury.

Best practices will be incorporated into the guidance created, since most of the best practices related to TRBs have not been written down. They would fit what Van Dusen calls "understood" polices. Faults with this verbal system include the fact that information is passed on through mentoring and word of mouth, meaning no two employees receives the exact same information on best practices. Additionally, not all groups within AFRL are equally aware of the existing best practices. When these best practices are used they have contributed to the success of AFRL's rocket test programs. A major reason for my tasking in the creation of the Test Operations Handbook was to document these best practices for the purpose of standardization and training to continue and possibly improve test program success.

Literature Review

A literature review was performed as part of this study, as was discussed in Chapter 2. The literature review consisted of five major categories: Complexity in organizational decision making; Varieties of coping mechanisms; Organizational culture change; Meeting management; and Technical Reviews.

Most of the literature used for this paper came from the on-line version of the California State University, Bakersfield (CSUB) Walter Stiern Library. The searches were done in the ProQuest database with the boxes checked for full text documents only and scholarly journals, including peer-reviewed. Searches were performed using the following keywords: policies, procedures, checklist, Deming (both as author and document text), Total

Quality Management, TQM, meeting management, organizational decision making, complexity, and technical review.

Additional literature was found using internet search engines, readings from previous class assignments, and using the references listed in other articles. The book by Atul Gawande *The Checklist Manifesto: How to get Things Right* was recommended by Dr. Moore and Dr. Commuri. The pertinent Air Force regulations were obtained from the Air Force Research Laboratory.

The search for information on complexity in organizational decision making resulted in a wide variety of different source with the intent of getting a general overview of the topic. Articles that went into details on narrow topics were not used. Therefore, a small sampling of the literature was used due to the common theme that organizational decision making is complex and the lack of need for a thorough exploration of this specific topic as a part of this study.

The varieties of coping mechanisms and the organizational culture change sections of the literature search yielded an abundance of sources. In order to not dilute the overall focus of this thesis, a sampling of the information on those topics was used.

The meeting management section of the literature review also resulted in a large number of available references. Abstracts or introductions were skimmed for key words to narrow the base of articles to those relevant to the topic. Unlike the first two sections of the literature review, the review of literature on meeting management was wrapped up when the articles started to present redundant information.

The topic of technical reviews was not included in chapter 2. The literature reviewed on technical reviews appeared to be more related to a large, high-level technical review

meetings or very specific to the software industry. Most of this information did not apply to the technical review board process at AFRL. A fifth section of technical review was not included in Chapter 2, because the information on technical reviews that did apply to the AFRL TRB process was easily fit into one of the other four categories.

AFRL Public Release Process

The tie-in to work for the Air Force for this study necessitated its approval by the Air Force for public release. A position paper for master's thesis on *technical review board chairman guidelines for conducting technical review boards for rocket testing* was submitted into the process for public release. This paper was approved for public release and given PA #11219 and allowed this study to proceed in greater detail for the master's thesis topic.

There is an Air Force form that must be filled out and submitted for approval for any public release document. The creator of the document fills out the form, which contains several questions related to document classification. Then the program manager (or in this case the student) and the supervisor review the document and sign the form. The form is submitted to the scientific and technical information office. The scientific and technical information office, technical advisor, foreign disclosure office, and public affairs office all review and approve the document for public release. The rocket science and technology developed by AFRL is critical for maintaining Air Force superiority, and the public release process was established to prevent information from getting into foreign adversaries' hands.

This master's thesis was approved through the same process and has been give PA#?????

CSUB Institutional Review Board (IRB) Process

All students in the master's program are required to complete the CSUB IRB: Human Subjects Protection Training. The training was completed on March 11, 2011.

No interviews, focus groups, or surveys were performed as part of this study. All references to discussions with others are from past experience prior to starting the study and have not been recorded or documented anywhere. No reference was made to any individual, only reference to job titles or generic group descriptions were used in this study. Additionally, the Air Force reviewed and approved this thesis for public release.

Master's thesis projects are required to be reviewed by the California State University, Bakersfield Institutional Review Board to ensure all appropriate human subject safety measures are applied. The form titled "Is My Project Human Subjects Research?' was filled out and submitted to Dr. Commuri the faculty research mentor. He obtained the department chair's signature and submitted the form to the IRB. This study was reviewed and determined not to be human subjects research (appendix).

CHAPTER 4

Findings

Conducting a Technical Review Board Guidance

This study has resulted in the creation of guidance for conducting a technical review board for rocket test programs performed by the Space Missile Propulsion Division that will be helpful to TRB chairpersons and useful information for TRB members. The guidance is written specifically for the TRB chairperson as he is responsible for organizing TRB activities. The guidance created for conducting a technical review board is in appendix B. The guidance is in the Test Operations Handbook format used by the Space Missile Propulsion Division. The remainder of this chapter will explain the guidance and the criteria used when creating it.

Header, Footer, Format, Sections I and II

This section explains the standard format used for test operation handbook. The header contains a date in the upper left corner. This date is used to track the date of the draft prior to approval and is then replaced with the approval date once adopted. In the center of the header is the Test Operations Handbook number and revision. The handbook documents are given a number to allow them to be put in the procedure management system and take full advantage of the available database search options. The number starts with TOHB which stands for Test Operations Handbook. The middle portion of the number designates the test area the handbook guidance applies to or, in this case, AFRL as it is intended for use throughout the lab. The end of the number is a unique four digit number assigned to the handbook guidance once adopted, currently XXXX has been put in as a placeholder. The revision number follows the TOHB number in the form of Rev. X and for an initial release X

is 0. In the right hand corner of the header is the page number and total number of pages in the form of Page X of Y. In the bottom right corner of the footer is the title of the handbook guidance, which is placed there to assist looking through the handbook when multiple topics have been put together.

The Test Operations Handbook guidance has two columns for the discussion portion and then examples and attachments are at the end in whatever format is appropriate for that handbook guidance. In the upper left corner of the first column is the title of the handbook guidance, this section is titled *Conducting a Technical Review Board.* The first section is always the OPR, which stands for office of primary responsibility. The second section is always general information and includes the purpose. The second section also includes information about the specific guidance is applicable to what test activities. After the second section the handbook, sections are no longer standardize from one handbook section to the next, but instead are all broken down into parts specific to the topic of that handbook section.

Section III Prior to the First Technical Review Board Meeting

The purpose of section III of the guidance was to help the TRB chairperson in planning the TRB review for that program. The first paragraph of this section takes Lee's advice that meeting management is like program management, so it states that technical review boards should be approached and managed like a project. My personal program management experience has been that you always have limited resources and time to perform the required objectives on any program and a statement was included to the effect.

The next part of the section III is based on personal experience where the TRB chairperson should consult with several people prior to conducting TRB meetings. The AFRL-West Test Lead and the responsible branch chief(s) are the immediate management

authority the TRB chairperson is chartered by, and it is wise for the TRB chairperson to make sure that their concerns are addressed as part of the review. The TRB chairperson should consult the Safety Review Board (SRB) chairperson to work out a plan synergizing the reviews as much as possible. For example, the TRB may be reviewing a document for technical accuracy and if they include an extra few minutes looking at safety criteria as requested by the SRB chairperson it could save hours of reviewing the same document in detail later. Experience has shown that the amount of total time a program goes through the TRB/SRB process is less if the TRB and SRB chairpersons are working together. Surprisingly, not a lot of TRB chairpersons ask the program manager or test director if they have specific concerns they would like the review board to address, which they often do. Finally, the chairperson has to be familiar with all the review board member's area of expertise in order to plan the review, and therefore should talk to any TRB member they are not familiar with prior to making the plan of who should review each document.

The next three paragraphs relate to the checklist on page 4 of the guidance and the TRB chairperson, creating a specific list of topics for the TRB to review for the test program. The checklist itself will be discussed later in this section. The TRB chairperson will gather a list of all the topics obtained from consulting as previously described and what he decided to include from the checklist. It is important for the chairperson to make sure the review board membership contains all the expertise required to provide a good review and this is explained in the guidance. Finally, the chairperson takes the list and creates a preliminary plan of who will review each document.

The current practice for TRBs is for the review board to always review the procedures, but there is no consistence to what is reviewed other than the procedures. Some

TRBs have solely reviewed procedures, while other boards have reviewed procedures and one or two analyses, and still other boards have reviewed procedures, analyses, and the system design. Any of the reviews listed in the last sentence may be acceptable as long as the reason for what is reviewed has been thought out. Some TRB chairperson request specific documents from the test team to review, but frequently the TRB reviews what the test team decides to provide them. If section III is followed by a TRB chairperson he will be better prepared to perform a comprehensive review of topics, as the choice of what is reviewed will have been thought out.

Section IV First TRB Meeting

Section four explains what is expected at the kickoff meeting. The test team will present an overview of the program and the schedule; this is a current best practice. The TRB chairperson will present his plan and request feedback from the test team and TRB members. The request for feedback on the plan follows the theme of Staren's comments about requesting input on the agenda from the members and Lee's comments about the members wanting to contribute. The TRB chairperson presenting a plan for the reviews and requesting feedback will be new to the TRB process. This will allow the test team and TRB members to provide comments and plan their time and workload around TRB meetings.

Section V Document Review

The first paragraph starts with emphasizing the purpose of the TRB, which is to assess the technical soundness and adequacy of the approach to meet the test requirements. Then it states the TRB can also make recommendation for better designs and ways to meet the test requirements. This is followed by a warning against treating recommendations based on review board member preferences as if they are requirements the test team must

meet. Examples are then included to clarify this statement. This paragraph in the TRB document was created using several of the lessons from the literature review in mind, combined with my own personal experiences. Both the test team and TRB members have to be actively involved in the process for it to work, which follows Swiss's remark (1992), "….quality improvement requires strong worker participation." (p. 358) This paragraph provides boundaries for what should be a TRB technical risk versus a recommendation. TRB technical risks will not be ignored by AFRL management, thus requiring the test team to address them. TRB recommendations are advice given to the test team, but the decision is left to the test team. Having clear roles and responsibilities allows both the TRB members and the test team to make a contribution and take pride in their work. Tompkins stressed one of Deming's 14 points, that pride in your work is a major motivator and barriers to being able to take pride in workmanship should be removed, which was incorporated by the inclusion of clear roles and responsibilities.

The second paragraph explains why not all documents require the same level of review. Then it gives a few examples and ends with a statement that the level of review should be increased if major flaws in the document are found. This paragraph incorporates the principles of Swiss' comments on TQM being opposed to mass inspection because they shift the responsibly away from the designers. It is important for the test team to take the lead on the program and not the review board, and therefore the review should only be what is required to complete the task.

The peer review concept in paragraph three comes from Harkins' statements about having a detailed technical review prior to a design review. This paragraph and paragraph four are also written in the spirit of not shifting the responsibility away from the designers. It

further continues the concept of clearly separating the TRB member and test team roles, allowing both groups to take pride in their work. Paragraph four provides warnings against the TRB losing its objectivity and independence by taking the test team's responsibilities on as their own. This is done with the best of intentions and desire to help the test be successful. The paragraph ends by providing the TRB chairperson with a way to get the test team assistance if needed, without compromising the TRB process itself.

The final paragraph of this section proposes significant changes to the current TRB meeting practices. These changes are based on the literature review and personal experience. First, it takes the advice of Allen et al. and emphasis not meeting if the topic can be handled with E-mails. The TRB members get the document and provide comments by E-mail, and meetings are only held if there are questions about the comments. My experience has been that 75-90% of the comments received by TRB members don't require a discussion and can be accepted and inputted into the document upon recent. The TRB is then only meeting to answer the test team's questions or once a revised document with the first round of comments have been incorporated. This way the TRB meetings deal only with clarifications, evaluation of the test team alternate approaches or explanations of why TRB comments were not incorporated by the test team. I believe this will be a significantly more efficient way to perform TRBs. This paragraph ends with a warning about doing a group procedure step-by-step walk through of the procedures, as this is a common problem of many TRBs.

Section VI Verification and Validation Plan (V&V Plan)

The verification and validation plan is one of the most important and misunderstood documents that the TRB should evaluate. The V&V plan is the test team's approach to

ensuring the technical success of the program and in reducing the technical risks. The risk mitigation portion of the safety process is well defined and understood by test personnel at AFRL. Therefore, it was useful to include analogies to the safety risk mitigation process to assist in the understanding of technical risk mitigation process. The safety review process uses a hazard analysis to document how the safety risks on the program will be mitigated. The safety review board spends a lot of effort on evaluating the hazard analysis. The V&V plan is the technical equivalent to the hazard analysis, as it documents how the technical risk will be mitigated through inspection, analysis, or functional checkouts. The TRB is to evaluate if the test team follows the V&V plan will that lead to a high level of confidence of technical success.

Requirements for the program come from multiple sources and are translated into the V&V plan. The V&V plan is a complex checklist, as it contains requirements and then what steps will be done to verify those requirements are met. This is where Deming's lesson in implemented pertaining to the fact that quality only has meaning if it takes into account the customer's needs. The test plan, which is specifically spelled out as a source of requirements, is the customer's test document, explaining their test requirements. But this is a very narrow view of the customer, as the test team must also satisfy the requirements of Air Force management, whose requirements are documented in regulations, policies, best practices, etc. Hoyer and Hoyer stated (2001), "Somehow, someone must know what the requirements are and be able to translate those requirements into measurable product or service characteristics" (p.55) The first step in creating the V&V plan is to translate the broad view of customer requirements into something that is definable. The last sentence

defines what the TRB should expect to find in the V&V plan and it includes the lessons Chernak documents from the software industry.

Section VII Meeting Management

Landale expressed that it is important for a meeting be efficient, have action oriented objectives, and for the attendees to come prepared. Landales lessons are incorporated into the first two paragraphs of the section VII of the guidance.

Allen, Rogelberg, and Scott's work was the inspiration for much of the next two paragraphs. The third paragraph was based on their concept of allowing employees who are part of the group to opt out of meetings that don't require them. An opt out clause was included in the third paragraph. The fourth paragraph consists of their questions about when to have a meeting turned into criteria of do not meet if and reworded to reflect local practice. The fourth paragraph states meetings should not be held if E-mail can be used to deal with the topic, there is no expected outcome or action items from meeting, or the documents required for review were not sent out in advance.

Several authors commented on the importance of an agenda, and paragraphs five and six plus the sample agenda on page five of the handbook section incorporate their comments. The inclusion of date, time, location, purpose of the meeting, status updates, discussion topics, and topics for future meeting/schedule were inspired by Kloppenborg and Petrick's work. The required attendees is an extension of Allen, Rogelberg, and Scott's opt out clause by taking it a step further and letting TRB member know in advance that they don't have to be at that particular meeting if they are not required. Additionally, having the agenda sent out early allows the TRB members to opt out once they know the topics. The inclusion of required meeting preparation was based on the statements of Landale, Staren, Lee, Allen,

Rogelberg, and Scott on the importance of coming to the meeting prepared. Staren's advice to prepare an agenda and send it out early to allow people to give feedback and to plan is incorporated.

The final paragraph on meeting minutes and the sample meeting minutes on page 6 of the handbook section were based mostly on the works of Staren, Lee and Lazarus with adaptation to meet local practice. The statement that the meeting minutes should be sent out within two working days reflects Staren's statement about minutes being sent out in a timely manner. The requirement for new action items, responsible parties, and due date came from Lee and Lazarus' writings.

Checklist of Potential TRB Topics to Review

The checklist is divided into three columns. The first column is potential TRB topics, which have been divided into categories and, subdivided further. The recommended level of review is listed in the second column and gives an indication of how many or what type person should review the document. In some cases column two states that only a sample of the documents need to be reviewed. The final column is for the TRB chairperson to mark which topics will be reviewed, with notes at the bottom of the checklist. Gawande's advice on what was a good or bad checklist was incorporated into this checklist, which is why it is precise, to the point, and practical. Since this is a new checklist, implementation is only a first step. The checklist will require updates to optimize it usefulness based on TRB member inputs.

CHAPTER 5

Conclusion

Summary and Conclusions

AFRL has a long proud history of successful rocket testing, although there are enough examples of test that have gone wrong. The technical difficulties and hazards related to rocket testing require taking extra steps to make sure all goes well. The technical and safety review boards are used for this purpose. With a rapidly changing workforce and new challenges, it has become more important than ever to make efficient use of all available resources, especially personnel. Current TRB reviews are inefficient and of inconsistent quality. The guidance created by this study can assist the technical review board chairperson in running a more efficient and effective review.

The guidance incorporates lessons learned about complexity of organizational decision making, policies, procedures, checklist, organizational cultural change, quality assurance, and meeting management; based both on experience and a thorough literature review. The checklist created as part of this guidance will assist in making sure the TRB chairperson does not overlook a critical topic for review. Following the advice of Gawande, the checklist is clear, concise, and practical.

Recommendation 1 – Adoption of the TRB Guidance

The Space Missile Propulsion Division should adopt the TRB guidance following the standard handbook guidance review process. The guidance as it appears in appendix B should be treated as the first draft. This draft would then be distributed to a group of experienced test directors from the Experimental Demonstration Branch for review and

comment. Once their comments are incorporated, the revised draft would be distributed for review and comment to a group including safety, quality assurance, and personnel from other branches that perform rocket testing. The final product, with comments incorporated, will then be submitted to management for approval. Once approved the guidance will be processed by the Configuration Management Office and posted on the configuration management drive and in the procedure management system. This guidance will be reviewed and updated with inputs from the first few TRBs. After that the guidance will be reviewed periodically to determine if updating is required.

TRB chairpersons appointed from the time of adoption should receive a copy of the guidance prior to their first time serving as a TRB chairperson. Additionally, a first time TRB chairperson should be assigned an experienced TRB chairperson as a mentor. It has been my experience that a mentor is almost always available, but few seem to ask for one. If management were to inform a new TRB chairperson that a mentor is available most would consult with one or at the very least appreciate knowing one is available.

Recommendation 2 – Create a Similar Safety Review Board Guidance

Safety Review Boards and Technical Review Boards are similar processes just with different focuses. Guidance for conducting a safety review would be almost as valuable as guidance for conducting a technical review. The only reason TRB guidance is critical is because there is a larger pool of TRB chairpersons while only a small pool of SRB chairpersons, as SRB chairpersons can only come from the safety office. In current practice, the SRB process is far more standardized than TRB process. Despite this fact, the SRB process can still see significant improvement from the creation of guidance for conducting an

SRB. Additionally, the guidance would be useful for the training of new safety personnel and helpful for review board and test team members unfamiliar with the SRB process.

Another reason to create SRB guidance is to standardize the processes as much as possible between the TRB and SRB. A common practice is to have a combined TRB/SRB board. The combined board still has two chairs, to make sure both technical and safety are evaluated, but it means the membership is identical for the TRB and SRB. Any progress made towards efficiency in the TRB could be negated if the SRB continues with the previous less efficient process. An even greater efficiency could be gained by having the SRB follow a similarly efficient process.

Part of my job after the completion of this study will be to work with the safety office to create a similar guidance for SRBs. Once the SRB guidance is created there is the potential that the TRB and SRB guidance could even be combined for greater efficiency.

Recommendation 3 – Creation of Verification and Validation Plan Guidance

As expressed in the findings, the verification and validation plan is one of the most important and most misunderstood documents. Much of the misunderstanding of the V&V plan comes from the misperception that it is just another document to create, when it is instead the test teams plan for mitigating the technical risks of the program. Several times during this study I had to stop and refocus as I was starting to create V&V plan guidance instead of guidance for conducting a TRB. This guidance is needed to assist the test team in reducing risks associated with testing and the creation of the V&V plan document. V&V plan guidance will also result in a better TRB review, as the same information needed to create the document will assist in the review of the document.

Rocket testing at a research and development site will always have new types of technical risks associated with it, and therefore require new ways to verify the risks are reduced. The vast majority of the technical risks associated with rocket testing are something the AFRL test community has seen and knows how to handle. Many of the new technical risks can still be reduced by standard mitigation techniques or slightly modified versions of them. Having guidance for the creation of the V&V plan that explains standard mitigation techniques and what they are used for will result in lower risks on test programs.

Part of my job, but not part of this thesis, is to take what was learned from this study, best practices, and personnel experience and create a test operations handbook section explaining how to create a V&V plan. This guidance will include a description of the purpose of many of the most common checkouts performed.

Research Recommendation

As pointed out earlier, the TRB and SRB processes are similar just with different focuses. One element of the SRB process that is well defined is the risk matrix for rating safety risks as high, medium, or low. This risk rating is quantified by level of harm to a person or dollar amount of damage to the facility combined with a probability of occurrence. A risk rating is given to the hazard prior to mitigation and then another after risk mitigation has been implemented. For technical risks there is no equivalent to the safety risk matrix. A good technical risk matrix with a qualifying risk assessment of high, medium, or low would greatly assist and enhance the TRB process. Future research will be performed to create a good technical risk matrix.

APPENDIX A

CSU Bakersfield
Academic Affairs
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Institutional Review Board for Human Subjects Research

Date: 20 July 2011

To: Daniel Harbour, PPA Student

cc: Chandra Commuri, Public Policy & Administration

From: Steve Suter, Research Ethics Review Coordinator

Subject: Protocol 11-124: Not Human Subjects Research

Thank you for bringing your protocol, **"Technical Review Board Chairman Guidelines for Conducting Technical Review Boards for Rocket Testing"** to the attention of the IRB/HSR. On the form *"Is My Project Human Subjects Research?"* you indicated the following:

I want to interview, survey, systematically observe, or collect other data from human subjects, for example, students in the educational setting. **NO**

I want to access data about specific persons that have already been collected by others [such as test scores or demographic information]. Those data can be linked to specific persons [regardless of whether I will link data and persons in my research or reveal anyone's identities]. **NO**

Given this, your proposed project will not constitute human subjects research. Therefore, it does not fall within the purview of the CSUB IRB/HSR. Good luck with your project.

If you have any questions, or there are any changes that might bring these activities within the purview of the IRB/HSR, please notify me immediately at 654-2373. Thank you.

Steve Suter, University Research Ethics Review Coordinator

APPENDIX B

Conducting a Technical Review Board

I. OPR

AFRL/RZSO (Mr. Dan Harbour)

II. GENERAL INFOMATION

The purpose of this guide is to provide a common base for conducting technical review boards (TRBs) at the Air Force Research Laboratory (AFRL), Edwards Research Site for rocket test programs. This guidance applies to test activities requiring an AFRL/RZ-W Form 27, Experimental/Test Operation Safety Permit.

III. PRIOR TO THE FIRST TECHNICAL REVIEW BOARD MEETING

Technical Review Boards should be approached and managed like a project. Just like any project there is an objective to meet, schedule, and resources are limited.

Upon appointment a TRB chairperson should consult the following:

- The AFRL-West Test Lead and/or responsible branch chief(s) to find out if there are any specific topics or concerns she has that should be addressed by the TRB.
- The SRB chairperson in order to work out a plan to allow for a smooth transition from TRB to SRB.
  NOTE: All references to a transition from TRB to SRB assume the two review boards are separate. If the review boards are combined then the same is true, but it aids in the running of the combined TRB/SRB.
- The program manager and test director to find out if there are any specific topics or concerns they would like the TRB to address. Also, the program manager and/or the test director can supply a list of drawings, analyses, and procedures.
- Any unfamiliar TRB member. It is important to know each member's area of expertise.

The next step is to take the checklist on page 4 of this document and determine what topics should be reviewed. It is recommended to discuss this with the SRB chairperson as it could aid in the smooth transition from TRB to SRB.

Now you should have a list of topics to be covered by the TRB from the checklist, which incorporates discussions with the AFRL-West Test Lead and/or responsible branch chief(s), SRB chairperson, program manager, and test director. Review the list and compare the topics with the review board members expertise. If the review board members have the expertise required to provide a good technical review then proceed. If the review board members do not have all the required expertise to provide a good technical review, identify the missing expertise, and request assistance from the AFRL-West Test Lead and/or responsible branch chief(s) in filling the gap. Subject matter experts can be assigned to the TRB to consult only on the specific topics related to their area of expertise.

Take the list of topics and come up with a preliminary plan of who will be reviewing which documents, and the level of detail required for each review.

IV. FIRST TRB MEETING

The first TRB meeting is a kickoff meeting. The program manager, test director, and/or test engineer will present an overview of the program and the schedule. The schedule will include anticipated dates that documents will be available for the TRB to review.

The TRB chairperson will discuss the list of topics that will be covered by the TRB. Present his plan for who will be reviewing which documents. The test team and TRB members will provide the TRB chairperson feedback on the list of topics and plan.

V. DOCUMENT REVIEW

The TRB is to review and assess the documents for technical soundness and adequacy to meet the test requirements. The TRB can make recommendation for better system designs and ways to meet the test requirements. It is not the function of the TRB to make technical decisions for the program or to require designs meet the board members personal preferences. For example, a TRB determining that a system design is inadequate without a check valve separating the liquid run line from the nitrogen purge line is what the TRB should be presenting as a risk

to the program success. The TRB requiring system setup to be performed in a particular order due to review board members preference, and not because of a technical risk, would be inappropriate. The TRB could recommend the order to be changed and explain their reasoning to the test team, but decisions related to preferences should be left to the test team.

Not all documents require the same level of review. For example, a complex analysis performed by a professional engineer may only require a quick review by a board member or two to make sure the proper analysis was performed. While system design drawings would require several members of the board to review it and make recommendations based on their area of expertise. If major flaws in a particular document are found, then the level of review should be increased.

The test team should perform a peer review of all documentation prior to submitting it to the TRB. The TRB should not accept a document without a signed peer review page by at least two test team members in addition to the author. If documents are received without the peer review page, the TRB chairperson should not send the document to the TRB members until the signed peer review page is received.

The TRB should not accept poor quality documents for review. Past experience has shown this can turn the TRB into a design, analysis, or procedure writing group for the program, which defeats the purpose of an independent technical review. If the test team provides the TRB with poor quality documentation, then the TRB chairperson should return the document to the test team for improvement prior to submitting it for TRB review. If the test team continually produces poor quality documentation, then the TRB chairperson should request the AFRL West Test Lead and/or responsible branch chief(s) provide the test program with someone with the required expertise to assist.

When documents are submitted to the review boards, the TRB chairperson will distribute them to the TRB members that will be providing the review of that document. The TRB members will E-mail comments to the TRB chairperson, program manager, and test director. A meeting will only be held if there are questions about the TRB member's comments. The program manager and test director will have the document revised and resubmit it. The TRB members will review the revised document and then a meeting will be held to discuss any questions and comments that were not incorporated by the test team. The TRB members sitting around the table doing a step by step group walk through of the procedures most likely means either the test team has provided a poor quality document, the TRB members have not come to the meeting prepared, or the TRB has elevated the level of review and decided to make themselves the procedure writing group.

VI. VERIFICATION & VALIDATION PLAN (V&V plan)

The V&V plan is one of the most important documents for the TRB to evaluate. The V&V plan is the test teams approach to ensuring the technical success of the program by reducing the technical risks. The V&V plan is the technical equivalent to the hazards analysis used to reduce the safety risks on the program. The V&V plan lists the inspections, analysis, and functional checkouts that will be performed to provide confidence the test will be successful. The TRB is to evaluate whether the test team's following of the V&V plan will lead to a high level of confidence of technical success.

Requirements no matter the source (test plan, regulations, best practices, etc.) are translated into the V&V plan. The V&V plan should include where the requirements come from, how to detect compliance, and what type of inspection, analysis, checkout or combination of these will be used to verify the systems are ready for test.

VII. MEETING MANAGEMENT

Due to the fact that the TRB members, including the TRB chairperson, are doing these reviews in addition to their normal program work, it is critical that TRB meeting are an efficient use of time.

TRB meetings need to have action oriented objectives. Everyone must come to the meeting prepared and with their out of meeting action items completed.

Only the TRB members required to cover the topics for that meeting should be at the meeting. TRB members should be allowed to miss the meeting if the topics being covered are not related to their area of expertise.

Meeting should not be held if any of the following are true.

- The topic can be dealt with through E-mails.
- No expected outcome or action items would result from the meeting. Don't hold regularly schedule TRB meetings just because the scheduled day comes.
- The documents for review were not sent out in advance to allow TRB members to prepare for the meeting.

It is important for each TRB meeting to have a well organized and thought out agenda. The agenda should start with the most critical topics. (See sample agenda on page 5 of this document.) The following should be included in the agenda

- Meeting Date, Time and Location
- Purpose of the Meeting
- Required Attendees
  NOTE: Not all members are required at all meetings. Only those with the expertise required for that meeting's topics should attend.
- Required Meeting Preparation
- Status Update on Action Items
  NOTE: List only those that will be discussed at that meeting
- Discussion Topics
- Topics for Future Meetings/Schedule:

The agenda should be prepared and sent out enough in advance for TRB members and test team members to provide feedback. Doing this allows the agenda to be used for planning and preparation. TRB members can then inform the TRB Chairperson if the list of topics does or does not fit their area of expertise. Additionally, it allows TRB or test team members to inform the TRB chairperson if an action item is not going to be completed in time for that meeting's discussion or if there are other schedule changes.

Meeting minutes should be sent out within two working days after the meeting. (See sample meeting minutes on page 6 of this document.) Meeting minutes should include the following

- Meeting Date and Time
- List of Attendees
- New Action Items, Responsible Parties and Due Date
- Action Item Status Updates
- Decisions Made
- Topics for Future Meetings/Schedule

Checklist of Potential TRB Topics to Review

Potential TRB Topics	Recommended Level of Review	TRB Review
Design Drawings		
P&IDs	Multidiscipline Review	
Isometrics	Single Person Review	
Rigging Drawings	One or Two Person Review	
Electrical Drawings	EE, Electrician, or IT	
Layout Drawings	One or Two Person Review	
Other Drawings	Varies Depending on the Drawing	
System Design		
Component Specifications	Single Person Review of a Sample of the Documentation Available	
Material Compatibility	Single Person Review of a Sample of the Documentation Available	
Remote Valve Fail Safe Position	Single Person Review of a Sample of the Documentation Available	
Pressure Rating	Single Person Review of a Sample of the Documentation Available	
Code Compliance	Single Person Review of a Sample of the Documentation Available	
Cleaning Specifications	Single Person Review	
Instrumentation and Controls	Single Person Review	
Other Design Documents	Varies Depending on the Document	
Analysis*		
Structural	One or Two Person Review	
Flow	One or Two Person Review	
Thrust Stand	One or Two Person Review	
Relief Valve Sizing	One or Two Person Review	
Lift Plan	One or Two Person Review	
Waterhammer	One or Two Person Review	
Other Analysis	Varies Depending on the Analysis	
Procedures		
Test Operating Procedures	Multidiscipline Review	
Standard Operating Procedures	Multidiscipline Review	
Verification and Validation Plan (V&V Plan)**	Multidiscipline Review	
Non-Conformance and Corrective Action Report (NCAR)	Varies Depending on the Non-Conformance	

NOTES:
*The analyses to be performed are listed in the V&V Plan, but are spelled out separately here. The TRB should not just review what analyses are planned, but also the analysis itself.
**The V&V Plan will include a list of the analysis, testing/demonstration (functional checkouts), and inspections that will be performed as part of the program.

Sample TRB Agenda for Program X

Meeting Date: 25 July 2011	Time: 8:00 am	Location: Building 8351, Room 230
Purpose: To provide final comments on the documentation required for the X motor receiving and installation into the test pad. Status igniter system design review.		
Required Attendees: George Washington, John Adams, etc.		
Required Meeting Preparation: Review the rigging drawings, lift plan, motor move and installation procedures revisions and be prepared to answer test teams questions about TRB member comments and/or discuss TRB member comments that the test team did not include in the revision.		
Status Update on the Following Action Items: Igniter system design review		Responsible Parties: Thomas Jefferson, James Madison
Discussion Topics: Rigging Drawings Lift Plan Motor Move Procedure Motor Installation Procedure Test director to present modified plan for xxxxxx.		
Topics for Future Meetings/Schedule: Test Plan V&V Plan TOP		

Sample TRB Meeting Minutes for Program X

Meeting Date: 25 July 2011	Time: 8:00 am	Location: Building 8351, Room 230
Attendees: George Washington, John Adams, etc.		
New Action Items: Review igniter checkout portion of V&V	Responsible Parties: Thomas Jefferson, James Madison	Due Date: 2 Aug 11
Action Items Status Updates: Igniter system design review	Responsible Parties: Thomas Jefferson, James Madison	Due Date: Complete
Decisions Made: Rigging drawing, lift plan, and motor move procedures are ready for signature. Motor installation procedure is ready for signature once x has been added		
Topics for Future Meetings/Schedule: Test Plan – 2 Aug V&V Plan – 2 Aug TOP- 9 Aug		

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